Detector R&D

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The goal of the R&D program

The TPC concept is heavily based on ALICE studies

By working it this way we benefit from a gigantic effort ALICE invested to operate TPC at the highest rates, however, we do:

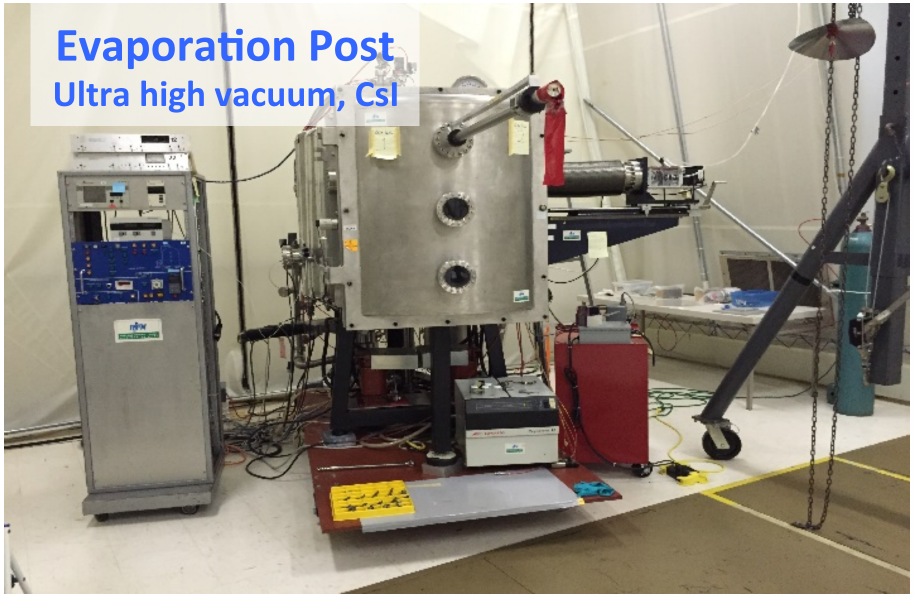
- need to optimize ALICE concept to RHIC needs
- prototype and test TPC elements
- not take critical parameters for granted
- not stop at what ALICE achieved

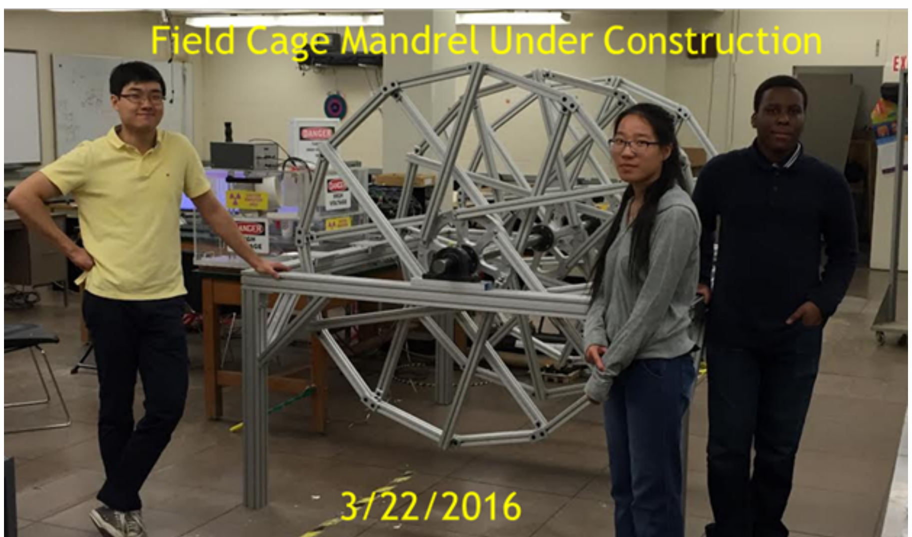
We have a crew of people who built PHENIX tracker and who worked out ALICE concept to built the sPHENIX TPC

And the EIC detector in the future.

Who are the people

Groups & Facilities

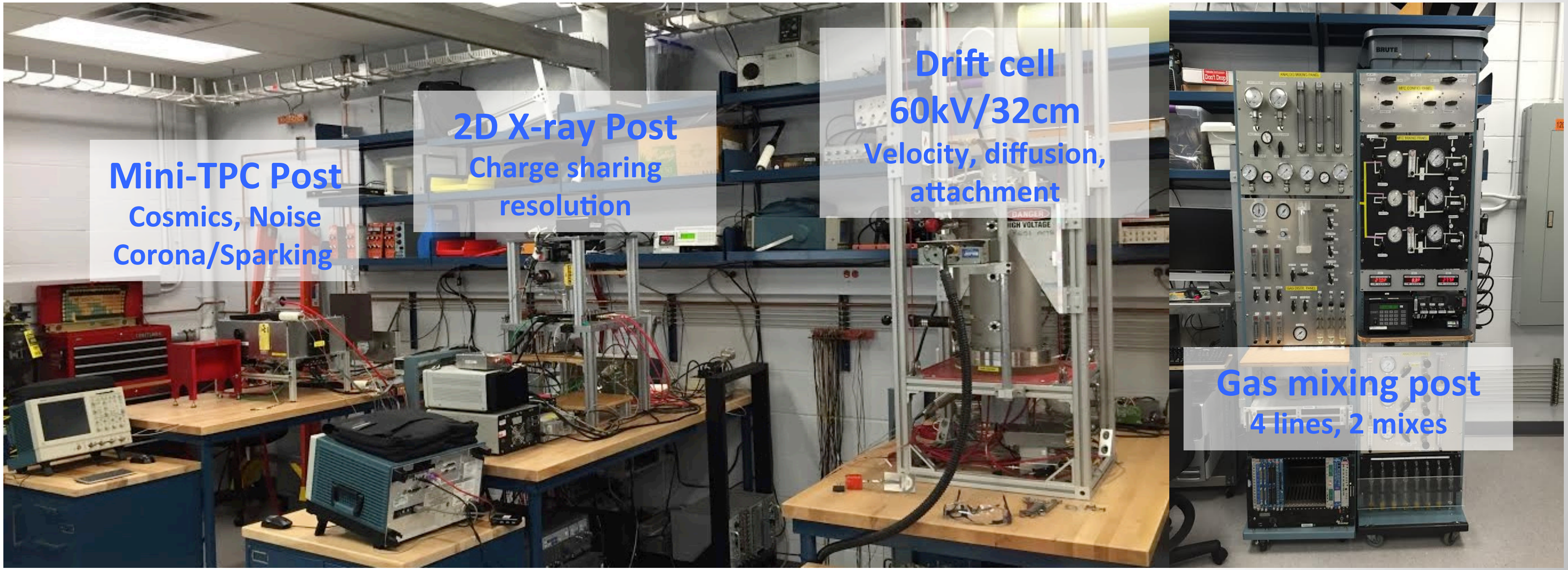




Stony Brook University

PHENIX Drift Chamber
PHENIX MPC-EX
PHENIX RICH
PHENIX HBD

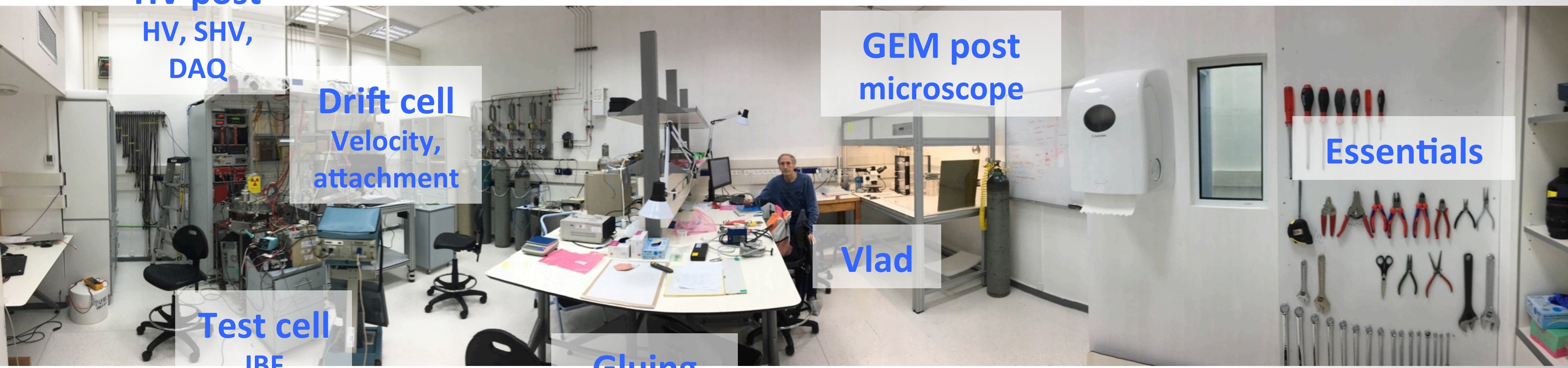
Groups & Facilities



PHENIX
PET

BROOKHAVEN NATIONAL LABORATORY

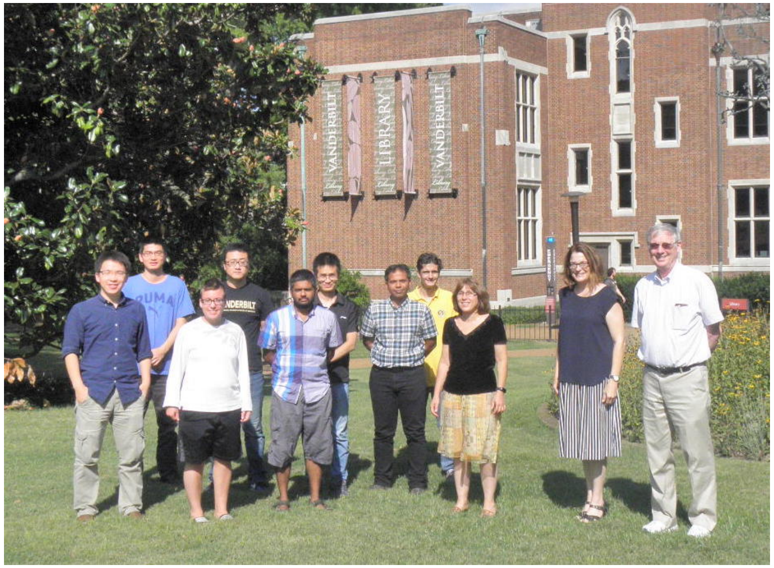
Groups & Facilities



מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

PHENIX PC1
PHENIX HBD
CERES TPC
CERES RICH
CERES PC

Groups & Facilities



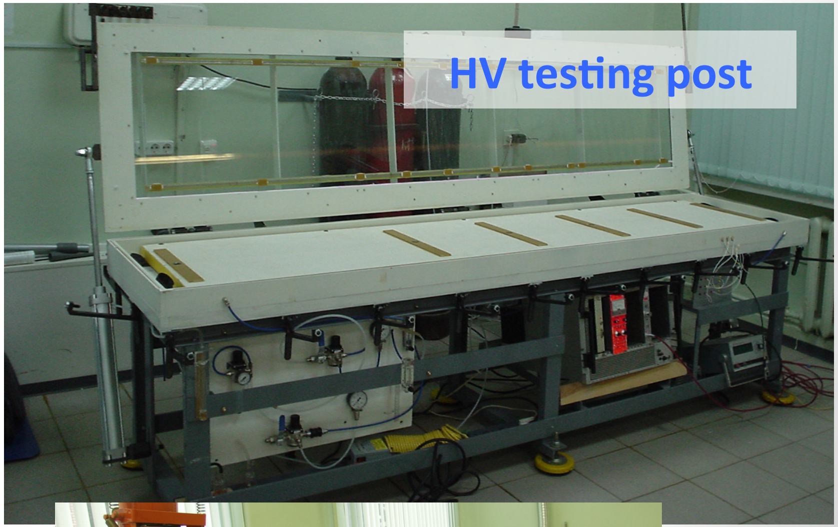
VANDERBILT UNIVERSITY

PHENIX PC2/PC3
PHENIX RPC
E864 and E814 Straw chambers

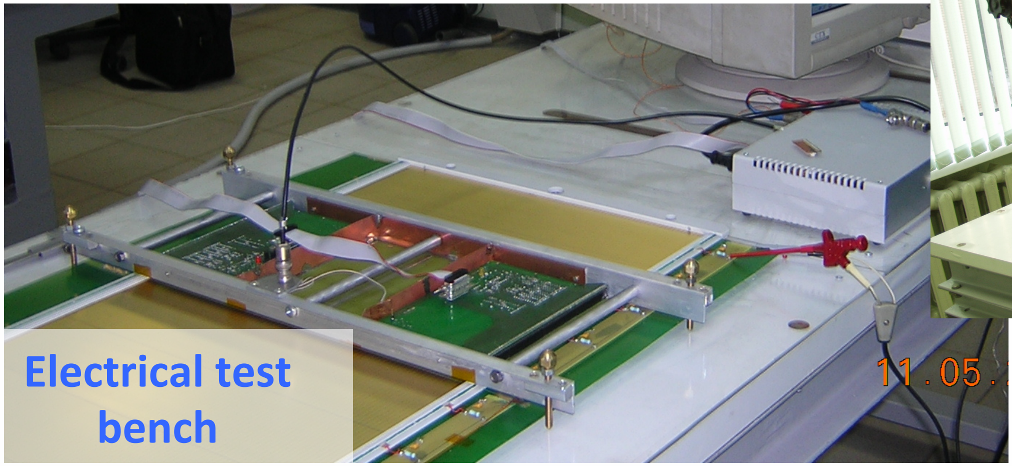
Groups & Facilities

Petersburg Nuclear Physics Institute (PNPI) of the Russian Academy of Sciences

Gas mixing post
3 in 1 out



HV testing post



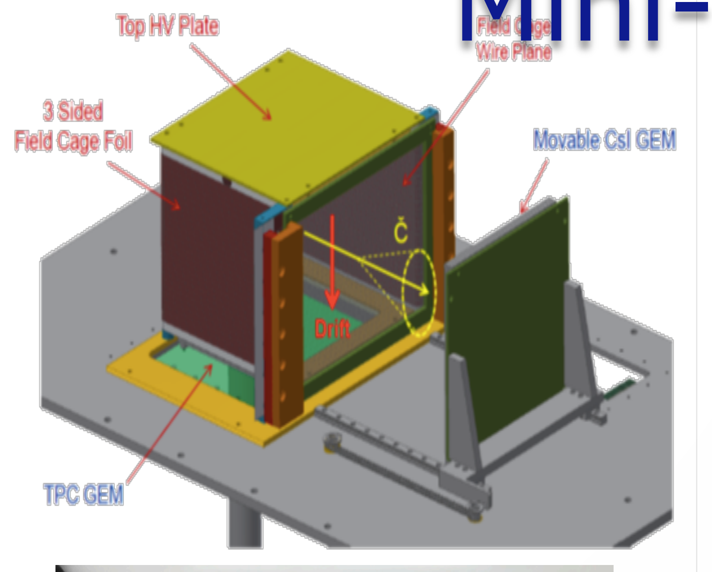
Electrical test bench

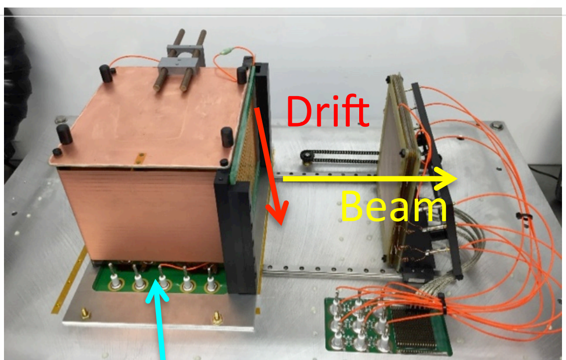
Technological table

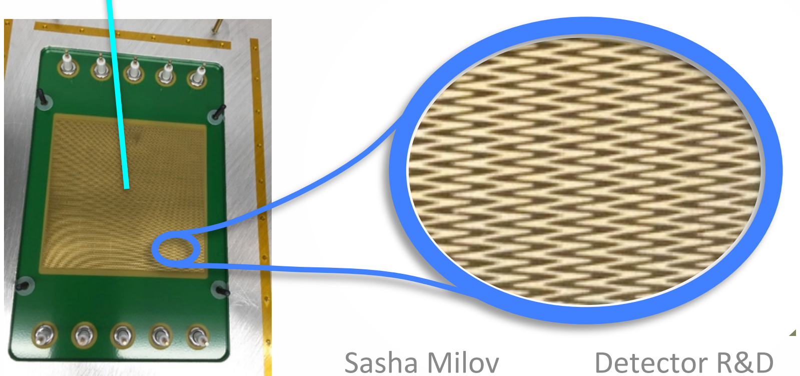
PHENIX DC
CBM RICH

Current R&D

Mini-TPC prototype







10cm drift

$10\text{x}10\text{cm}^2$ 4-layer GEM

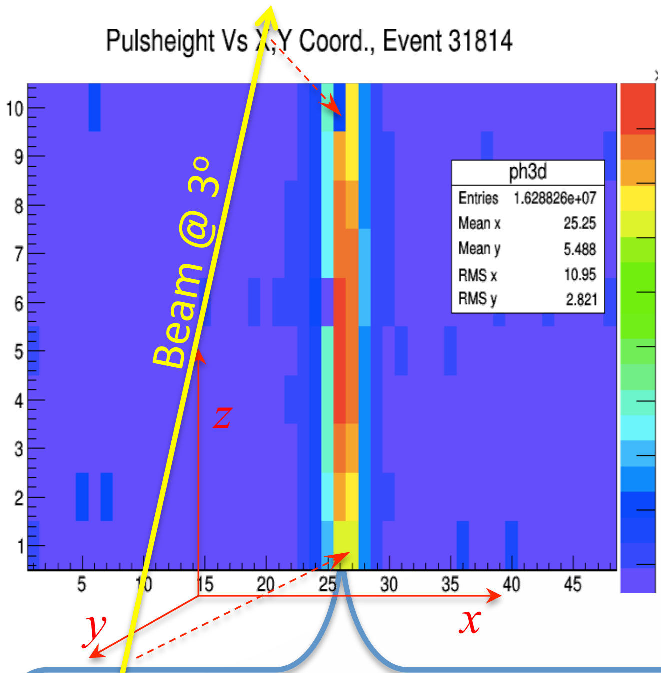
Pure CF_4: 7.5cm/us

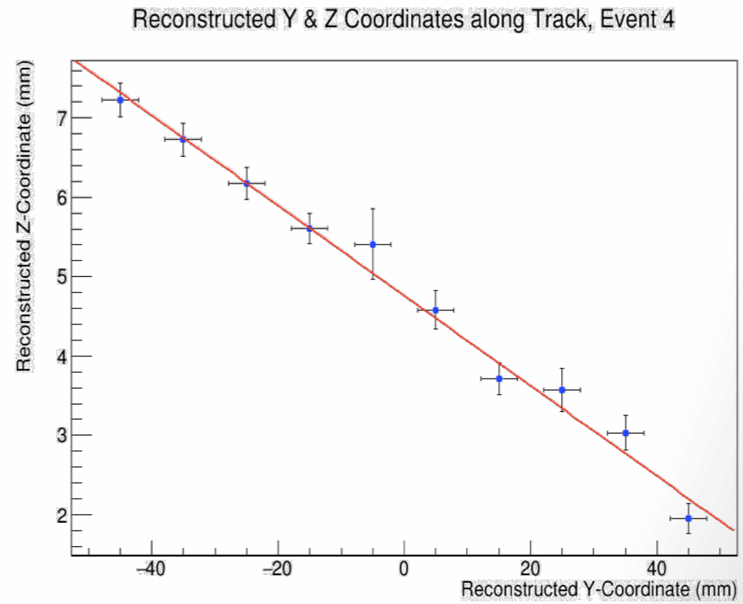
RCDAQ readout with 40MHz APV25/SRS

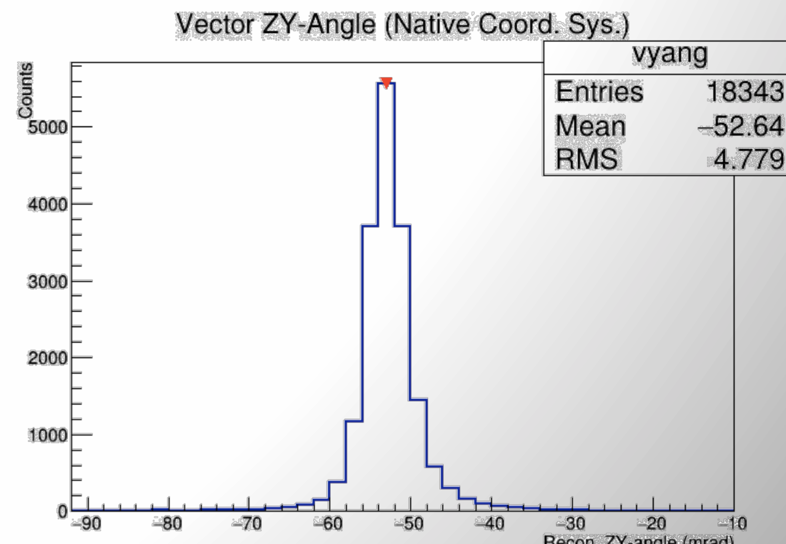
Zigzag (chevron) pad plane

Pads $2\text{x}10\text{mm}^2$

The TPC mode: 3D tracks







Charge sharing by 2mm pads allows using centroid to reconstruct x-coordinate

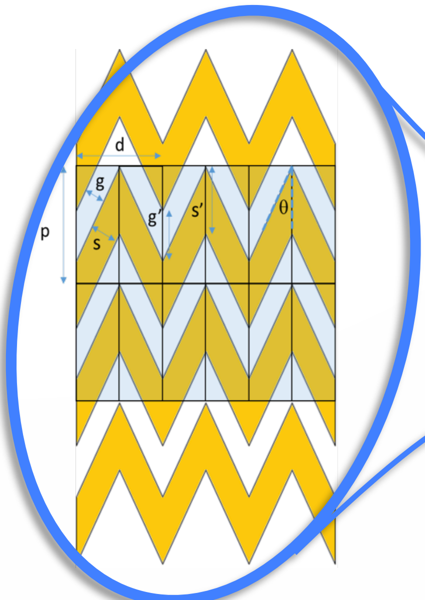
y-coordinate is measured by timing the charge arrival

y&z-coordinate (padrow) ➔ 3^o peak as the beam angle

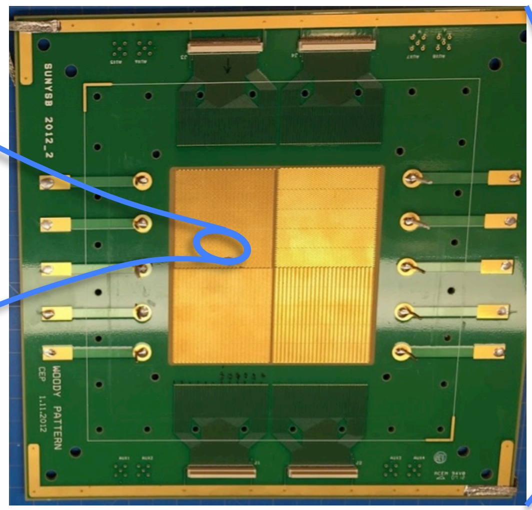
The TPC Prototyping: pads

Optimize resolution: More sharing – More accuracy
Less sharing – Less occupancy

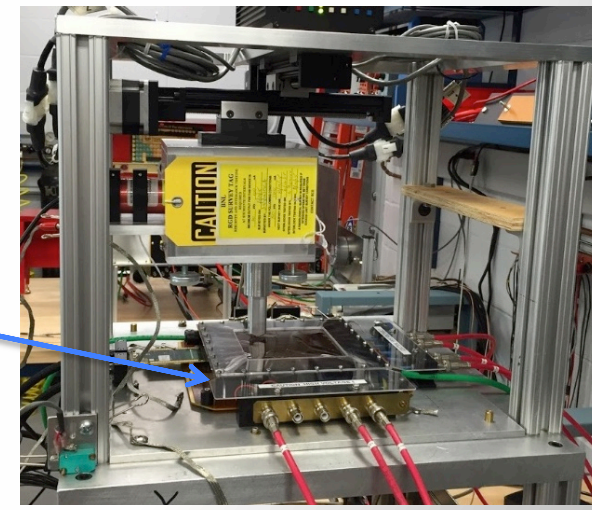
Goal: 100um resolution with 2mm pad structure
Linearity across the structure



Chevron patterns guided by simulation



Manufactured for testing in the lab condition



X-Y scan facility with collimated X-ray source

Pads: simulation

Chevron pattern is matched to the size of the avalanche

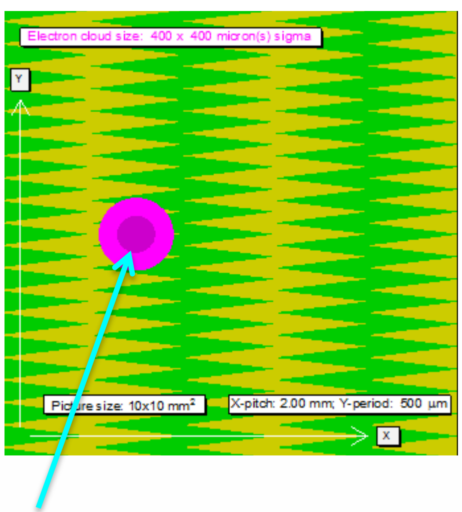
No avalanches in contained in a single pad

No pad collects more than 85% of total charge

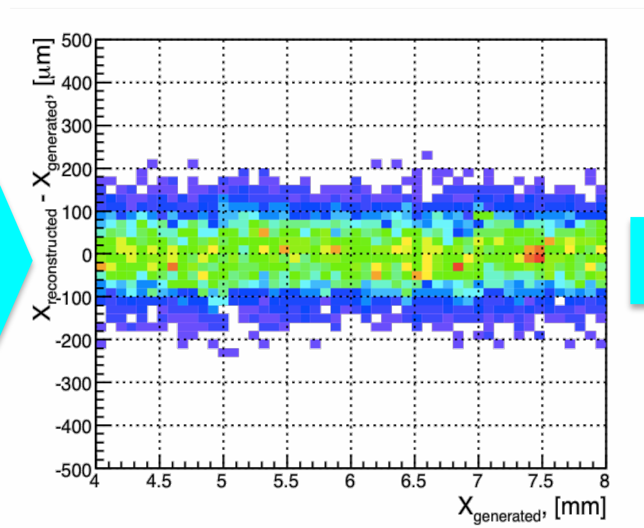
Minimize dependence on the avalanche size (200-600 um)

Minimize non-linearity along the pads

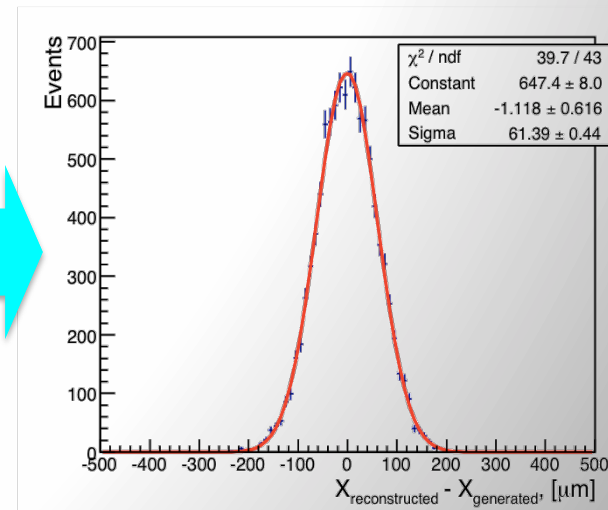
Choose design insensitive to small perturbations: variation of pad sizes, irregularities in gaps between pads, trace thickness, field distortions



2D Gaussian with N(e$^-$)×Gain+Noise

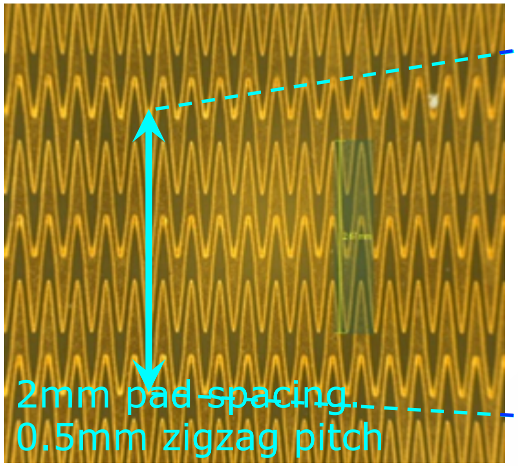


Pad response with field distortion (to be added) and cross talks

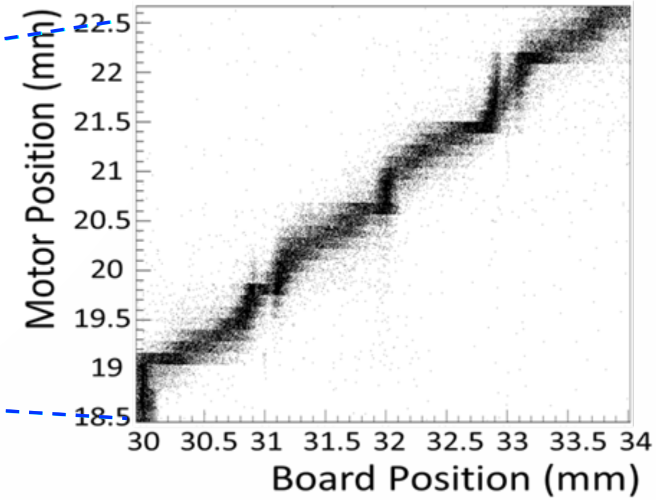


Analyze resolution and non-linearity

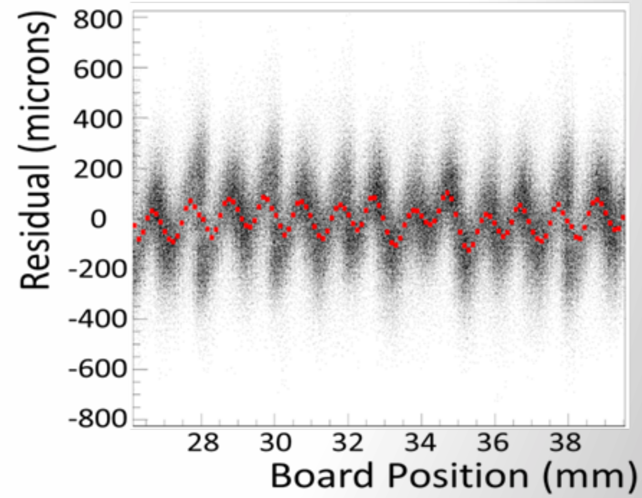
Pads: measurement



Reconstructed vs. nominal (measured)



Residual distortion

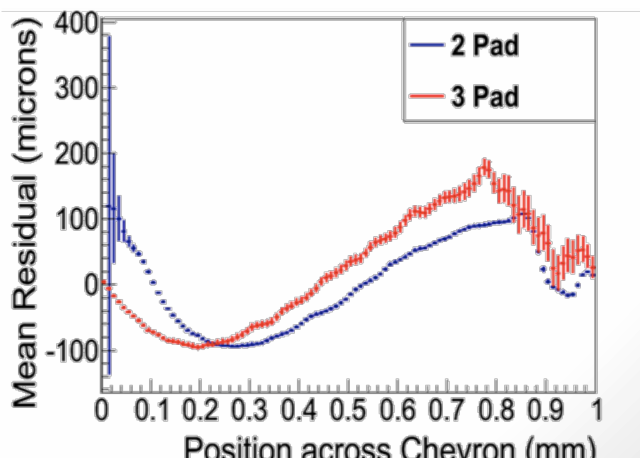


Ideally, we would like to have no distortions

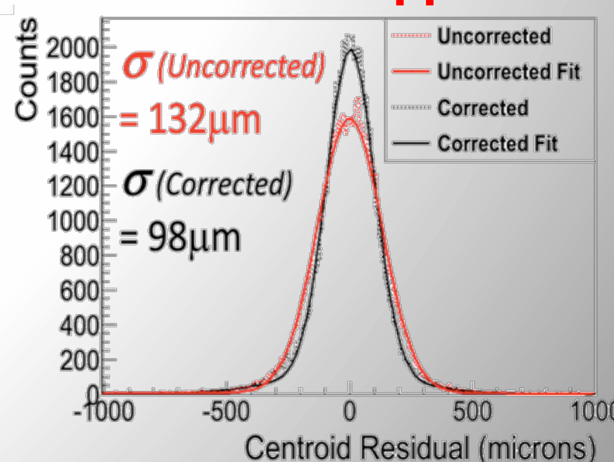
In reality it may not be possible.

Small distortions can be measured and corrected

Derived correction

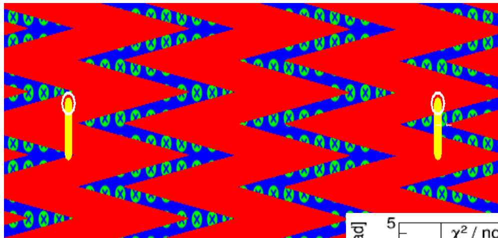


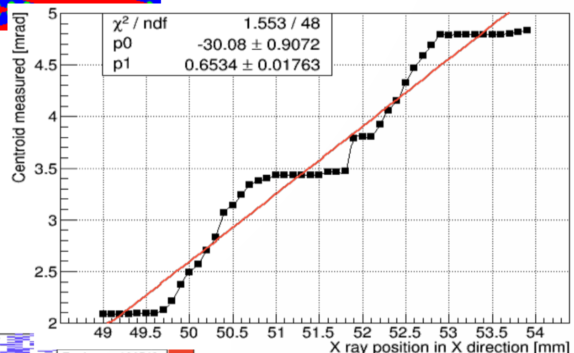
Correction applied

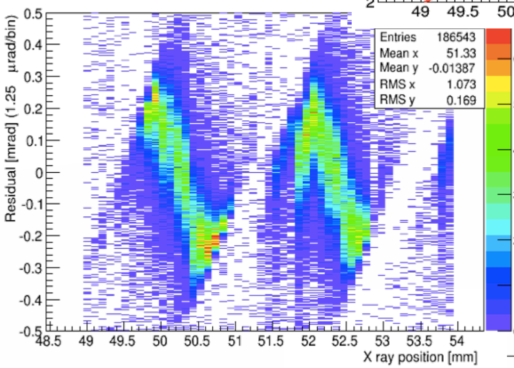


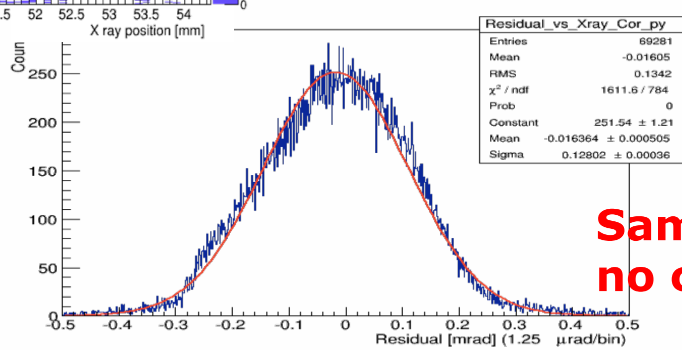
Pads: improvement

Original pad design

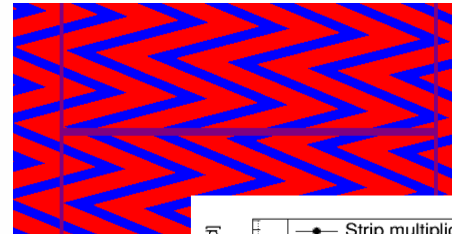


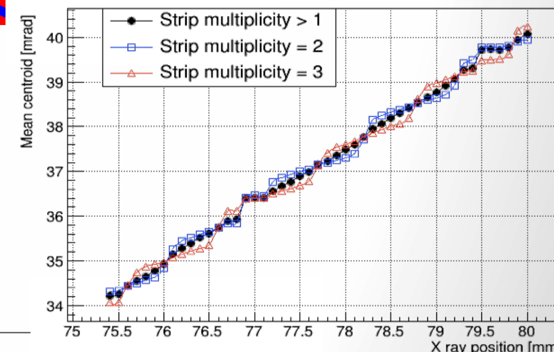


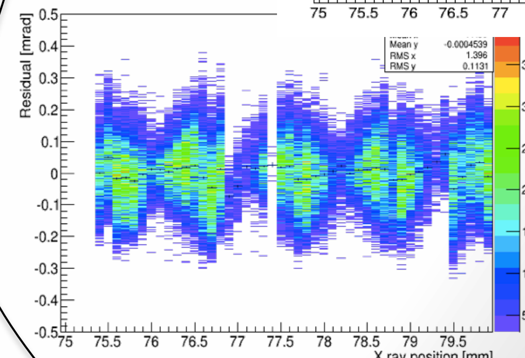


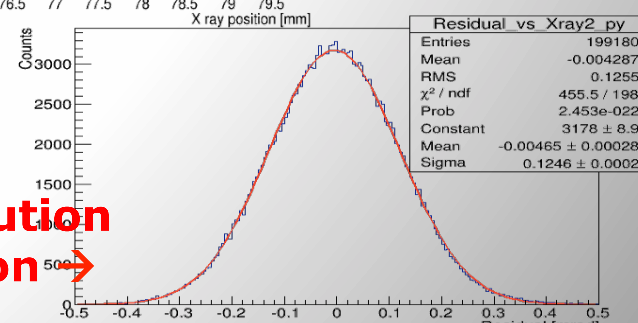


Improved pad design





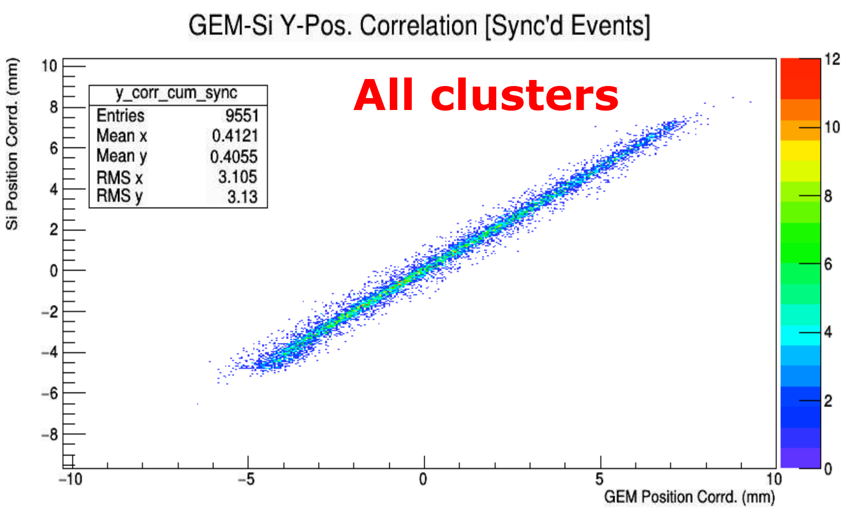


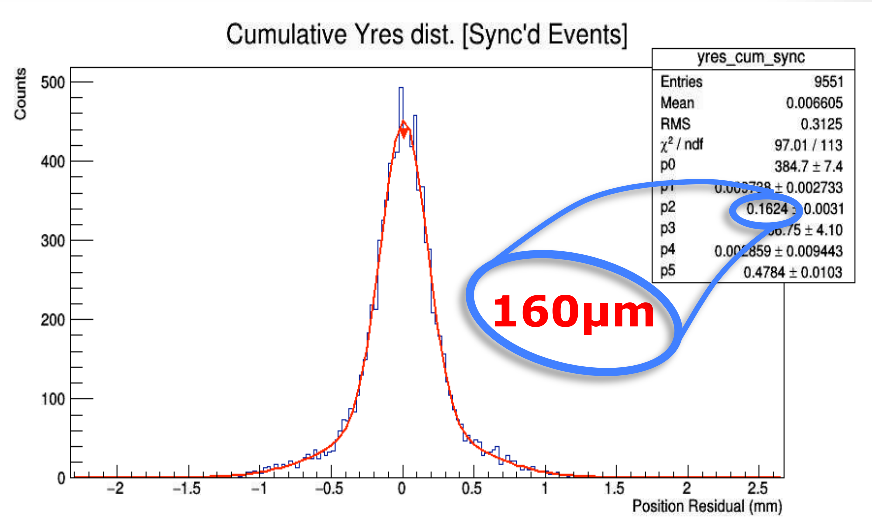


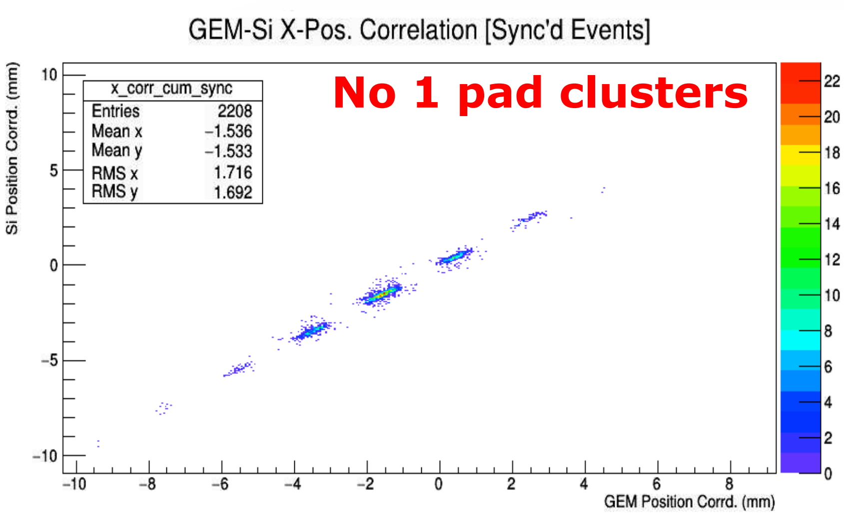
Same resolution
no correction →

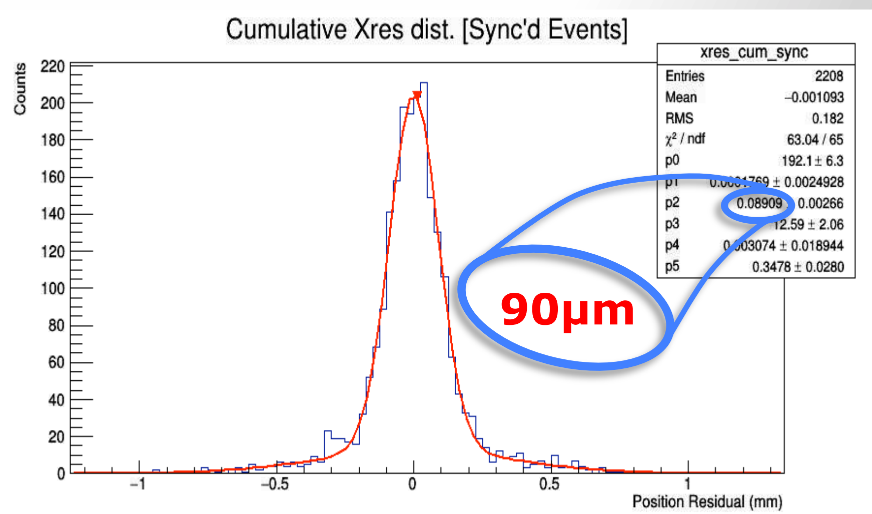
Pad hits → Track resolution

Single pad clusters are not very beneficial for the tack resolution

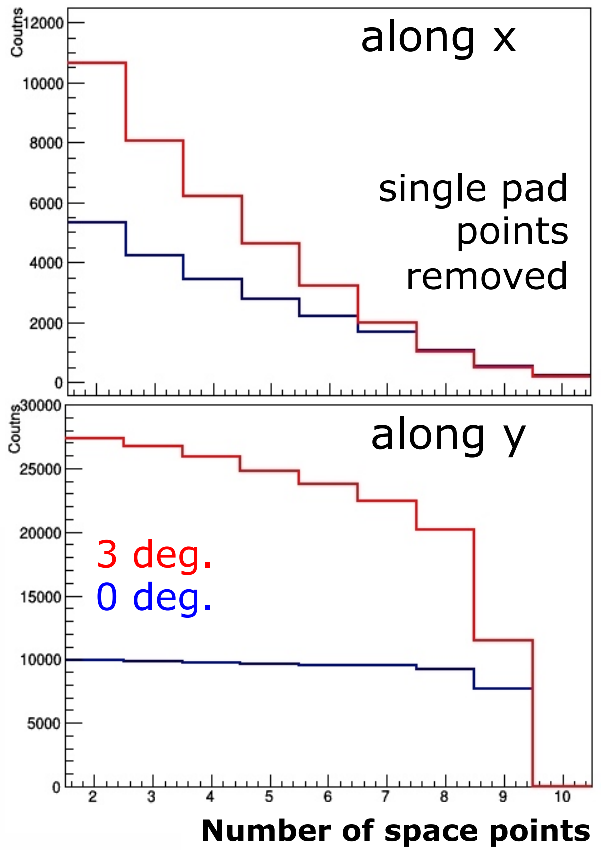


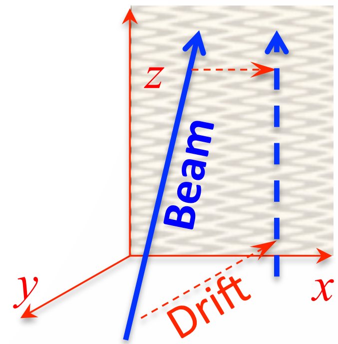






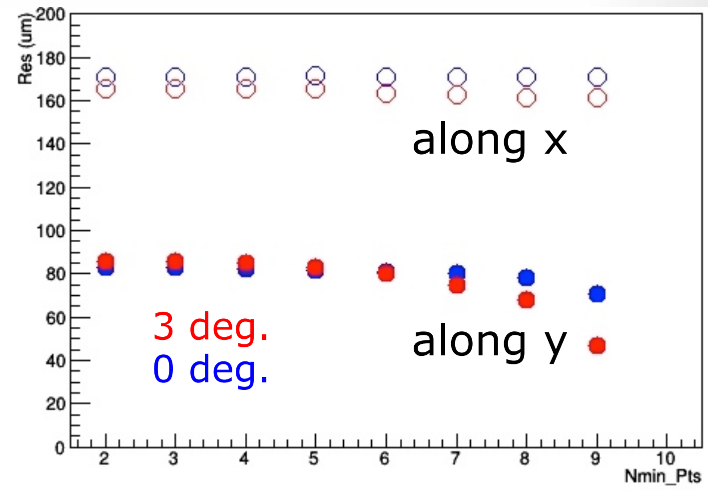
Hit quality → Track resolution



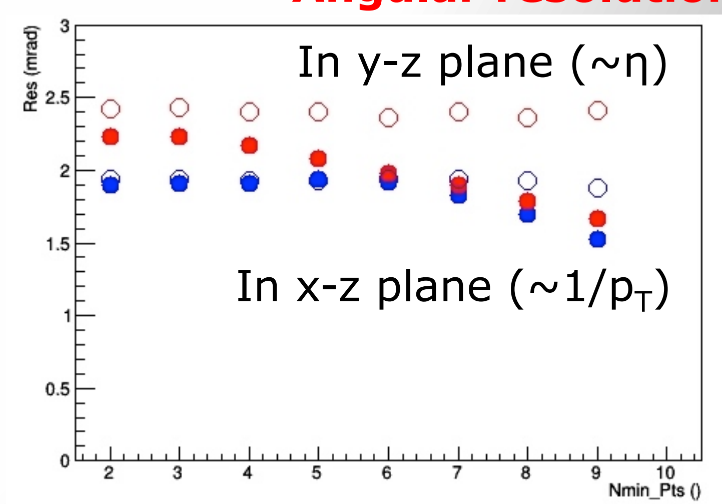


Number of space points with 2 fired pads plays critical role

Spatial distortion



Angular resolution

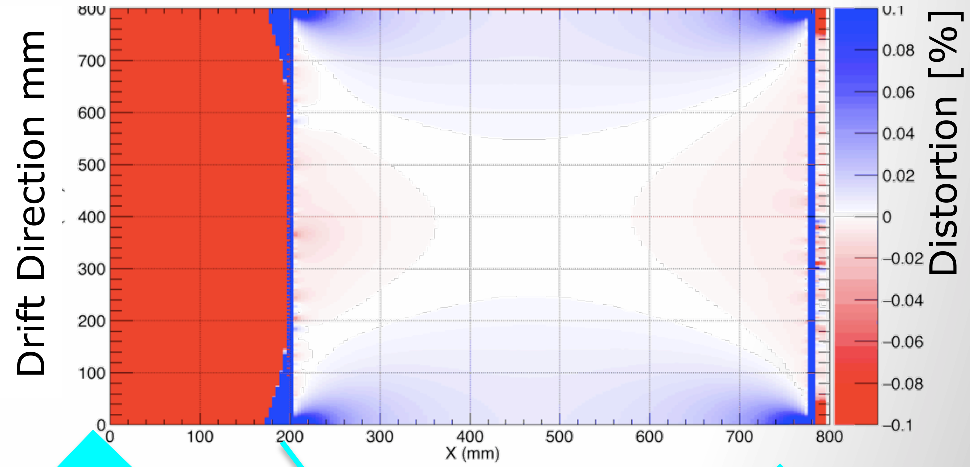


Field Cage

How mechanical tolerances affect the the drift field?

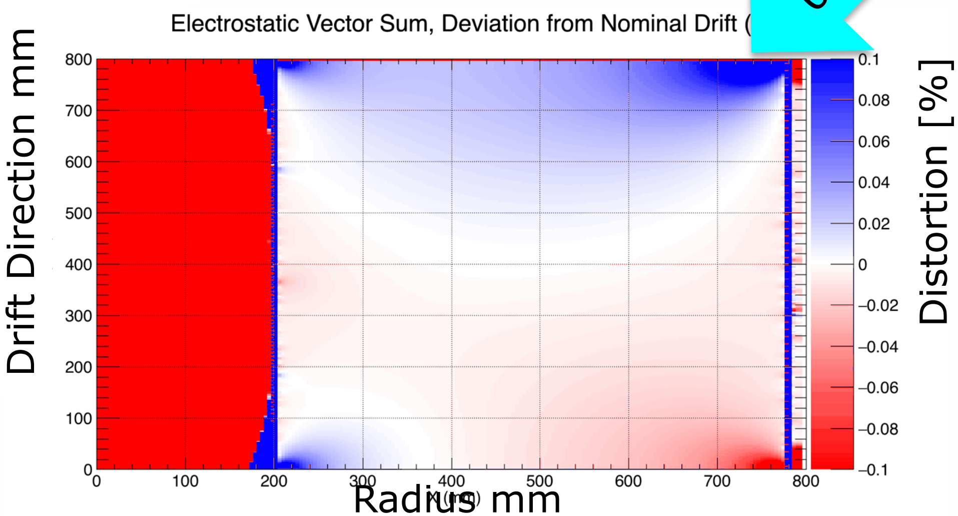
Using ANSYS

At the moment drift is 28 cm

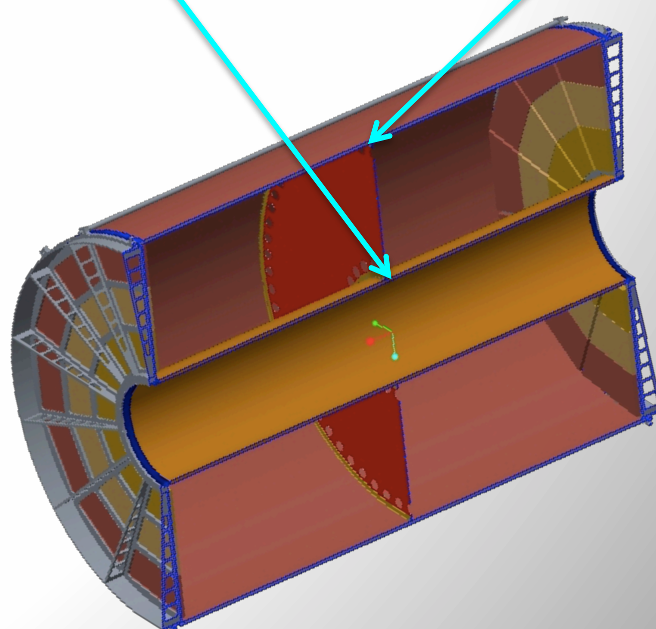


Radius mm

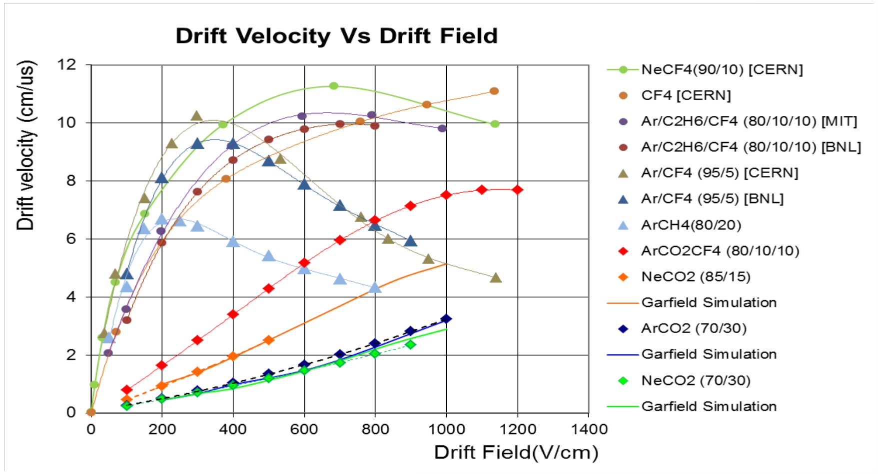
0.1mm offset



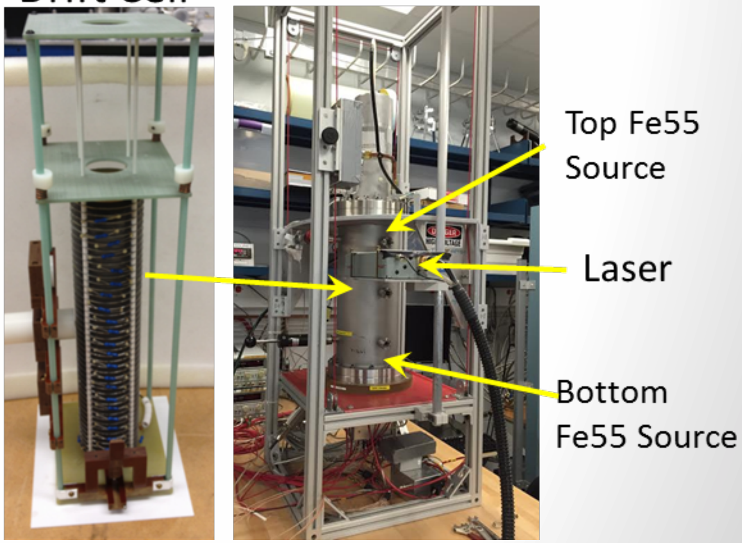
Radius mm

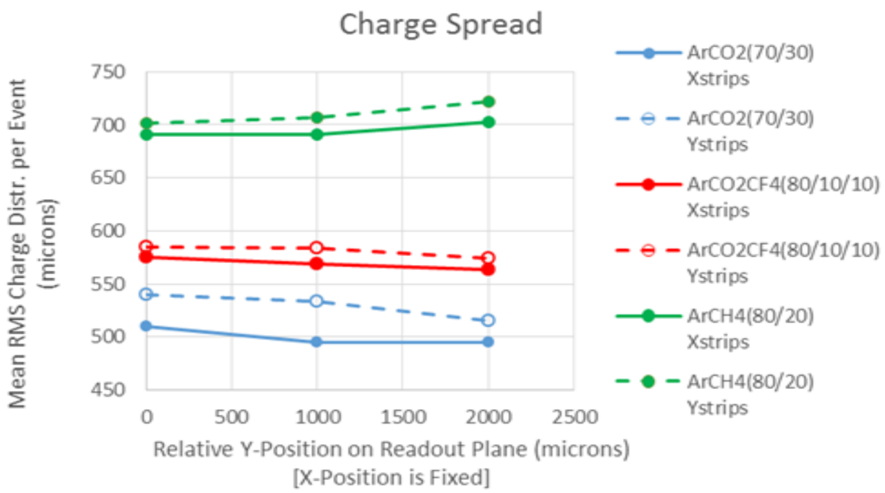


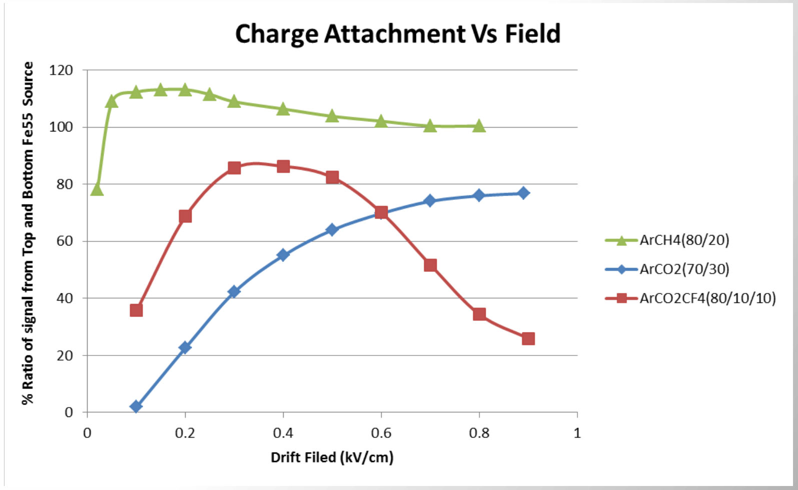
Basic gas properties



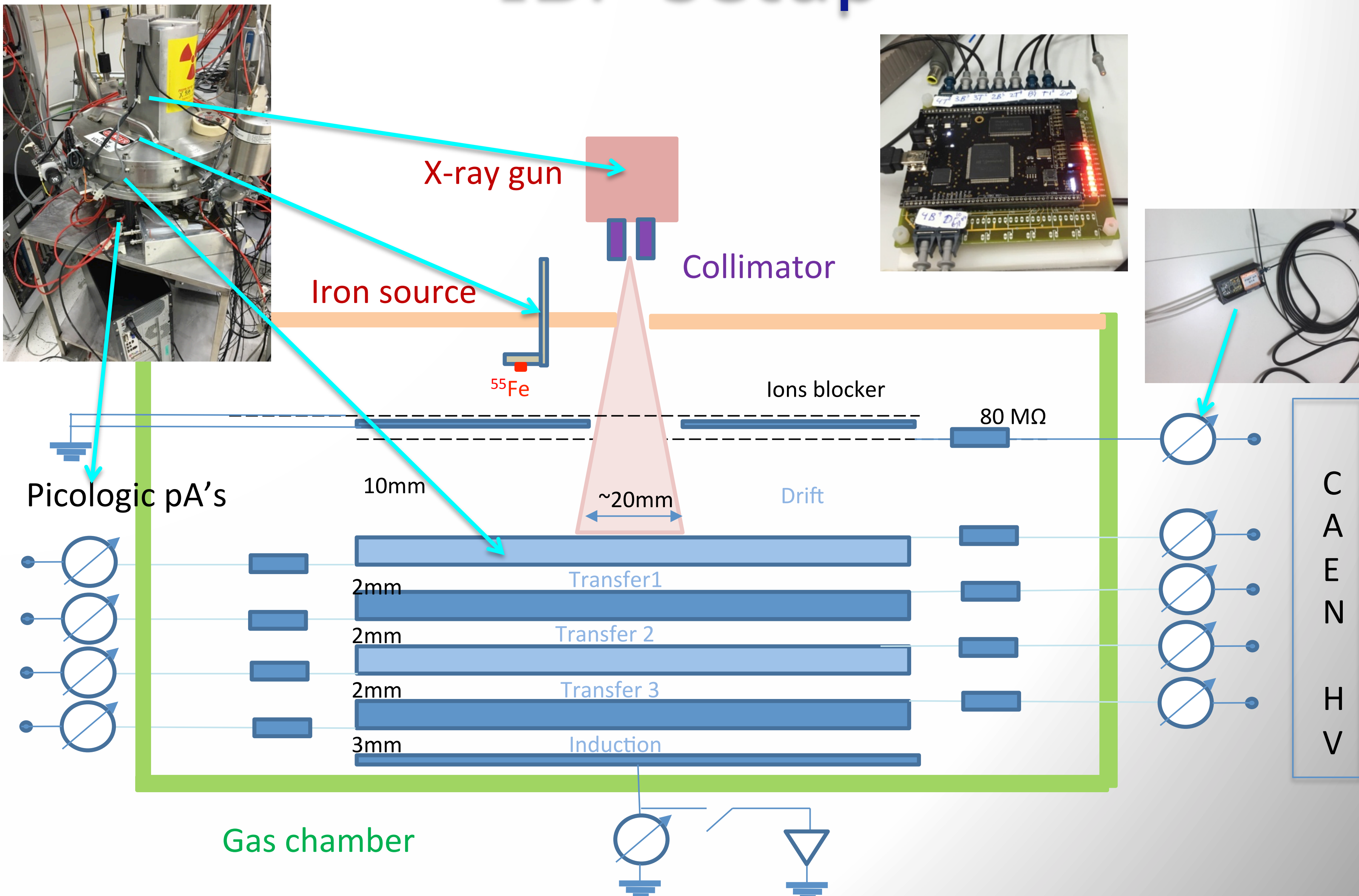
Drift Cell



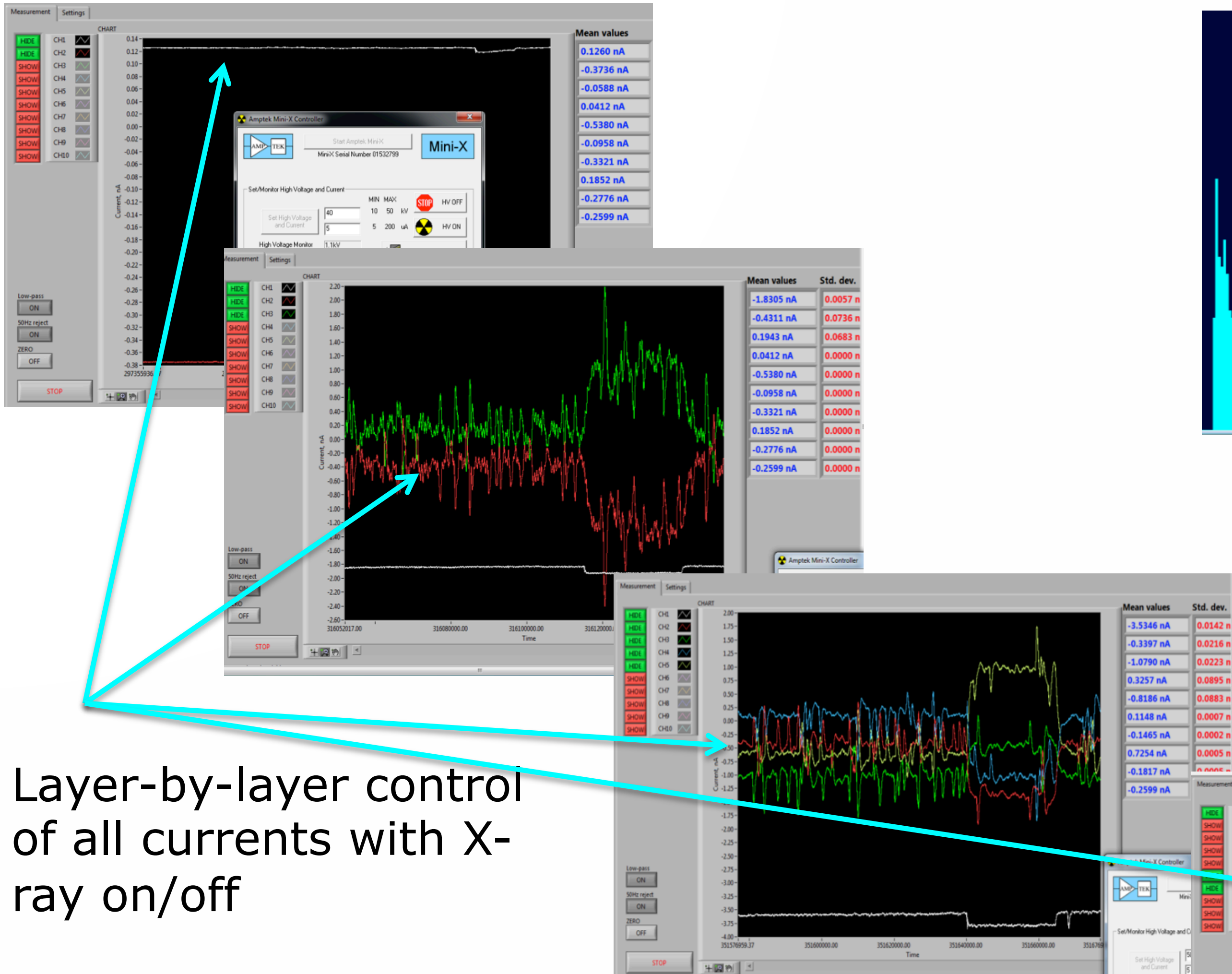


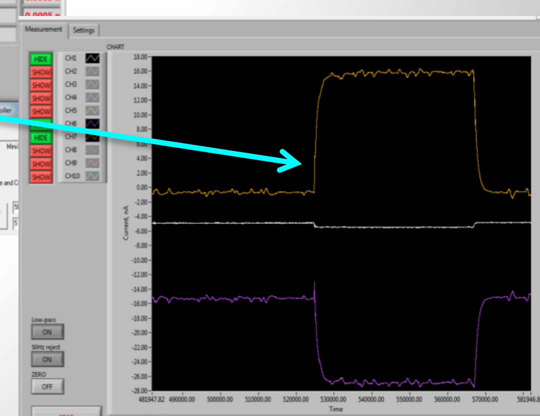


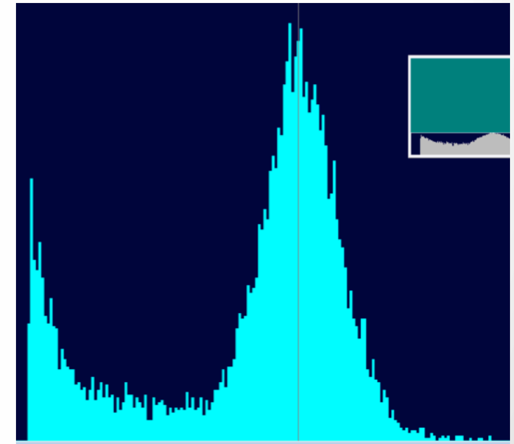
IBF setup


X-ray gun
Collimator
Iron source
^{55}Fe
Ions blocker
80 MΩ
Picologic pA's
10mm
~20mm
Drift
Transfer1
2mm
Transfer 2
2mm
Transfer 3
2mm
3mm
Induction
C A E N H V
Gas chamber

IBF measurement



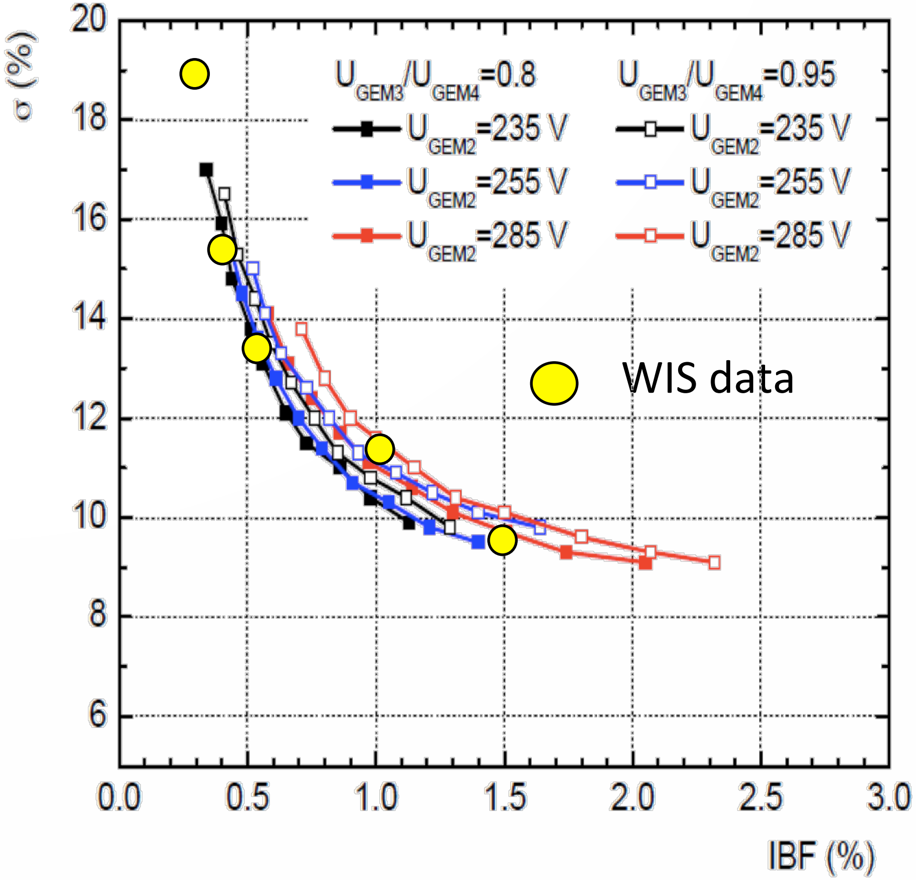




^{55}Fe resolution calibration gives IBF point

Layer-by-layer control of all currents with X-ray on/off

IBF results

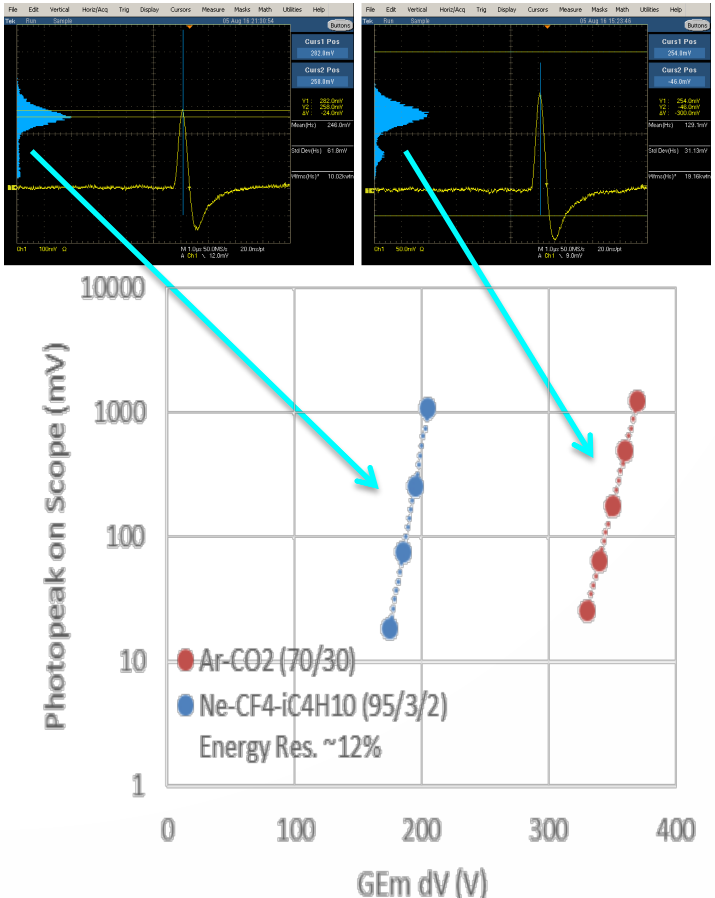


Gain ~2×10^3

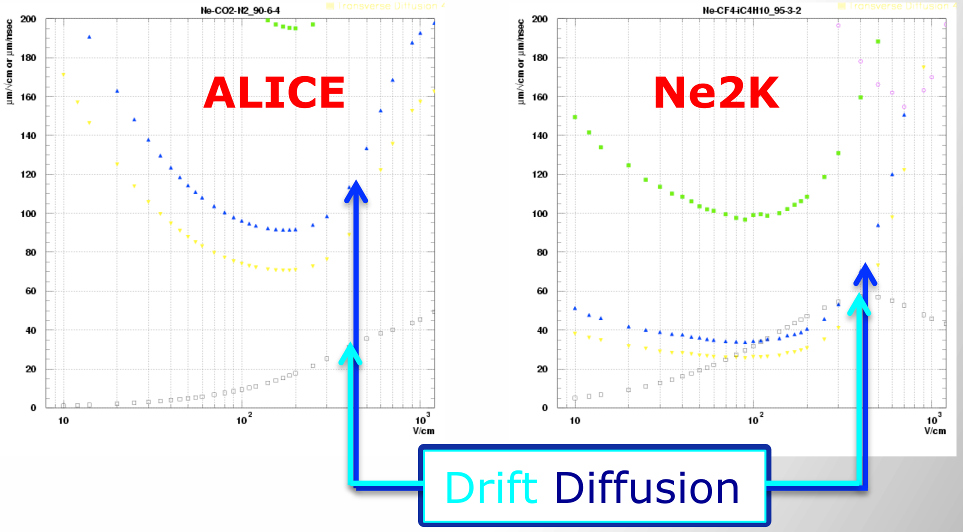
Element	S1	S2	S3	S4	S5
Drift	0.4	0.4	0.4	0.4	0.4
GEM1 (V)	275	270	245	320	300
Tr. 1 (kV/cm)	4	4	4	4	4
GEM2 (V)	255	255	235	235	285
Tr. 2 (kV/cm)	2	2	2	2	2
GEM 3 (V)	270	275	295	305	295
Tr. 3 (kV/cm)	0.1	0.1	0.1	0.1	0.1
GEM 4 (V)	360	355	370	385	310
Extr. (kV/cm)	4	4	4	4	4
Resolution %	11	14	16	20	10
IBF %	1.0	0.6	0.4	0.3	1.5

Ne2K

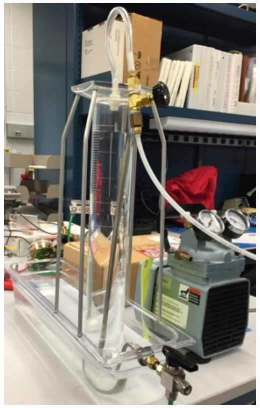
ALICE:	$Ne/CO_2/N_2$	(90/10/5)
T2K:	$Ar/CF_4/iC_4H_{10}$	(95/3/2)
Ne2K:	$Ne/CF_4/iC_4H_{10}$	(95/3/2)

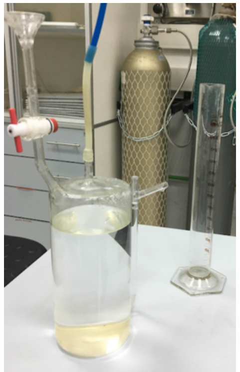


Stable working point, lower diffusion



American





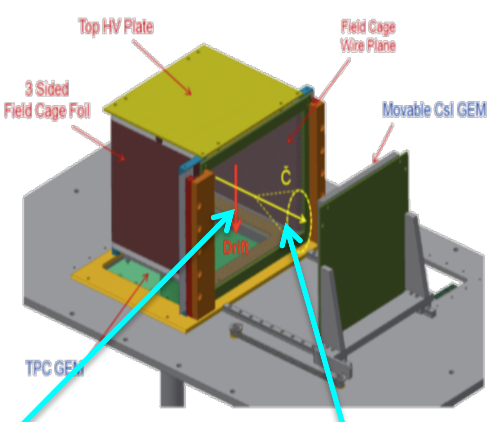
Asian

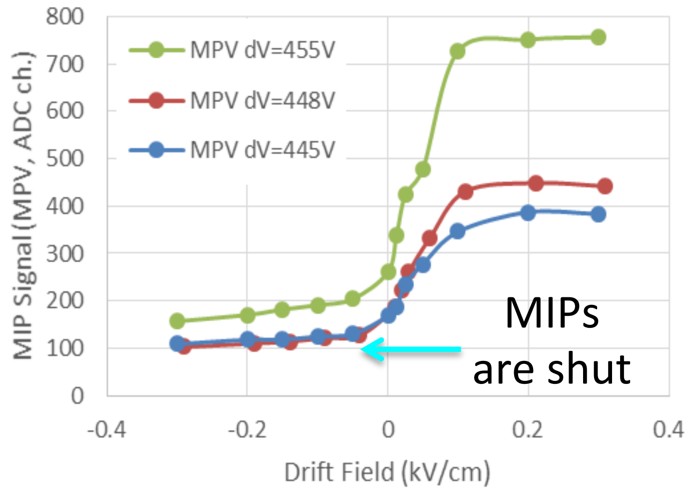
Ne2K has small gas fractions,

← no matter how modern the lab is, flow controllers must be calibrated.

Beyond the TPC

Mini TPCČ



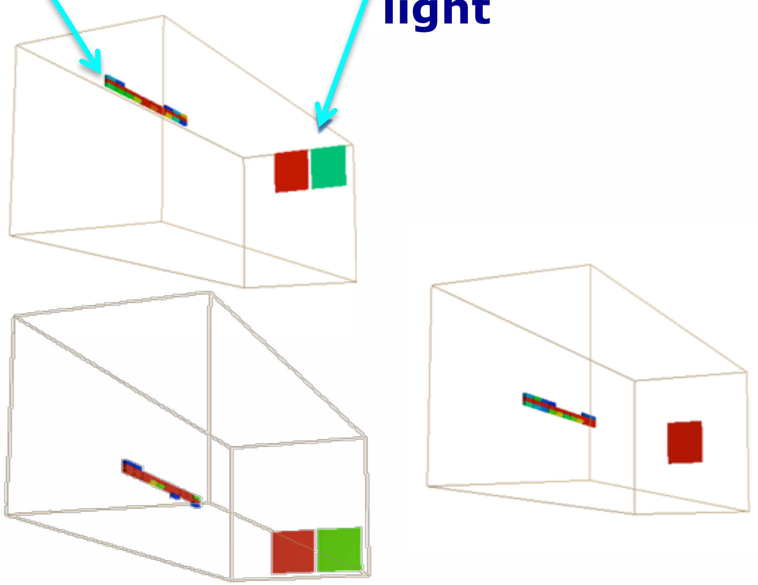


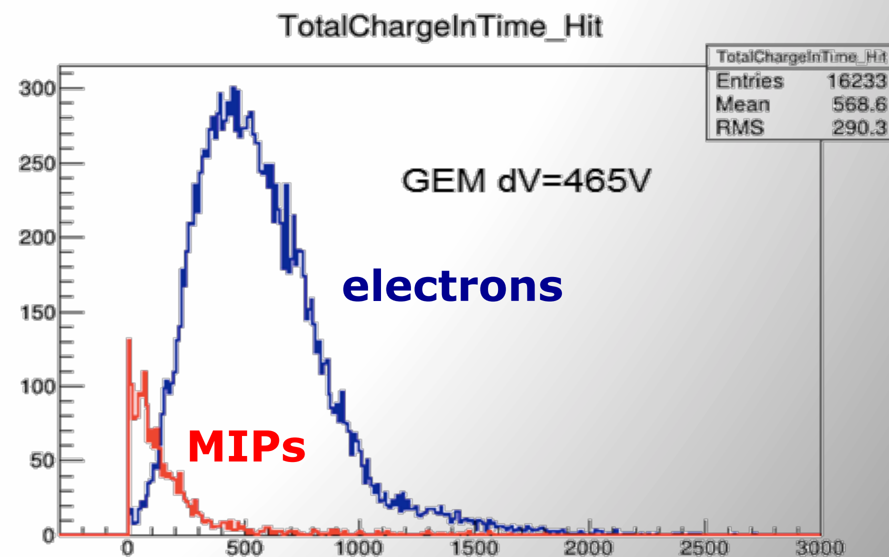
A step towards EIC:

TPC and Cherenkov detector are compatible in gas and commentary in geometry

Particle track

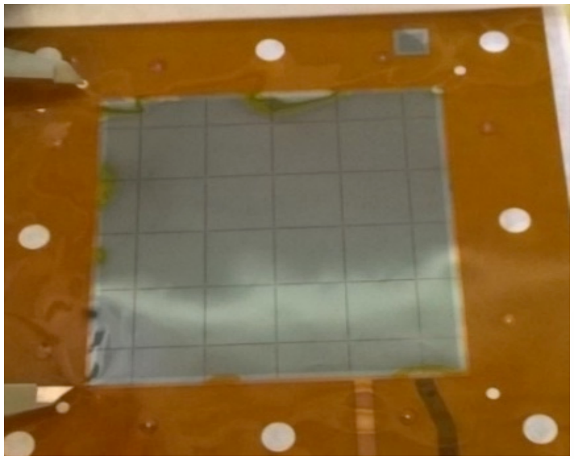
Cherenkov light

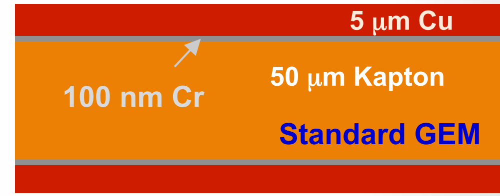




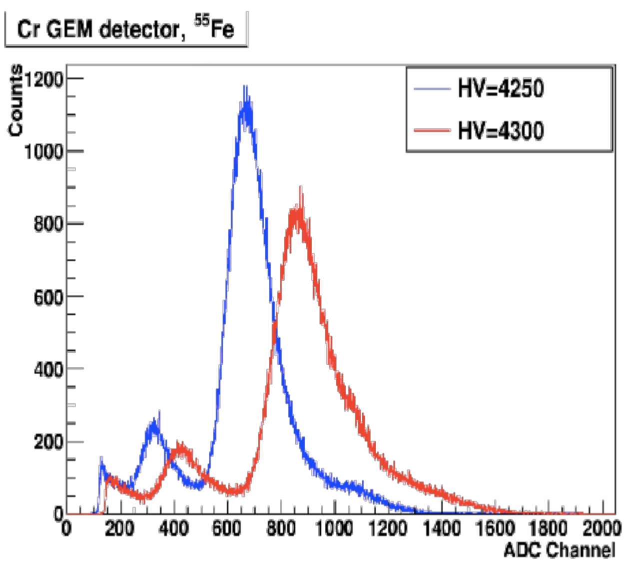
Chromium GEMs

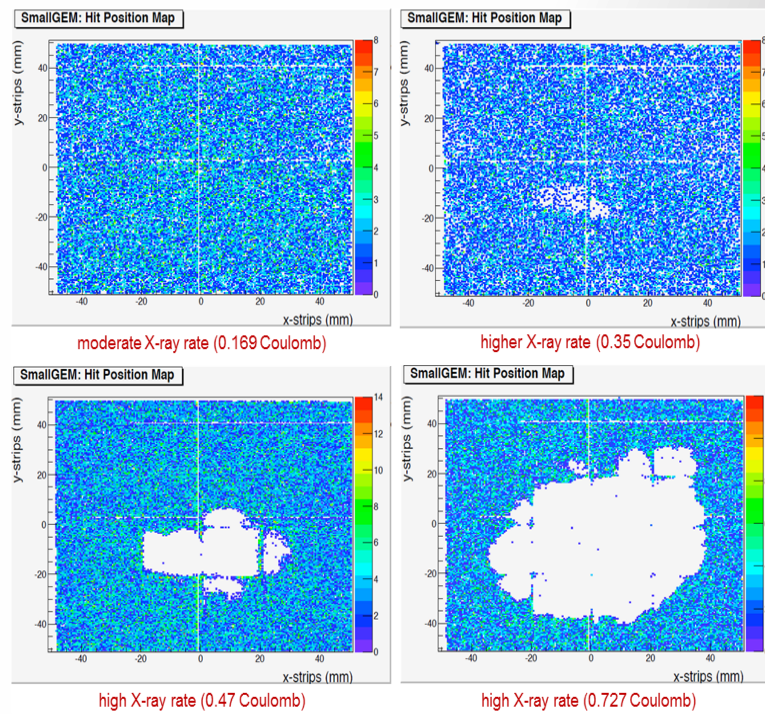
Thin GEMs are “thick”. About 50% of GEM mass is copper





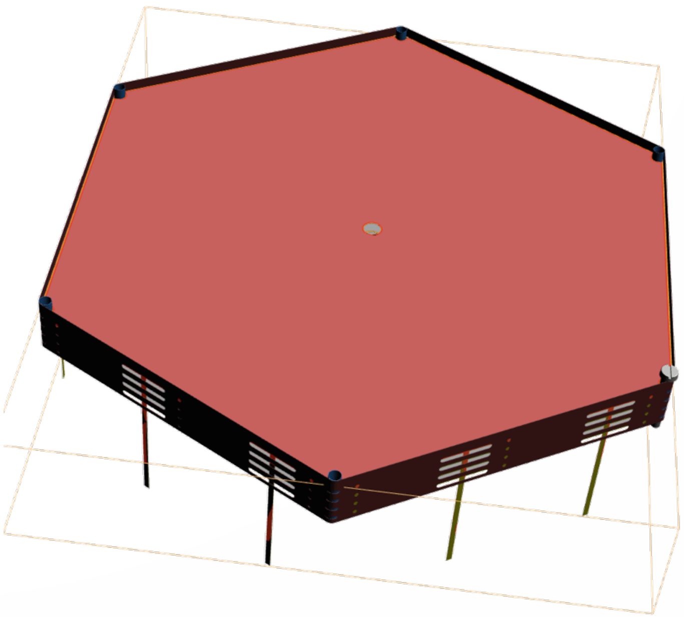
Copperless (Cr-GEM) gives uniform response, aging properties under study





“Frameless” GEMs

GEMs do not need heavy frames, there is no electrostatic force.



Smaller mass
Less dead areas
Easier to evaporate CsI

Summary & outlook

Beam tested Mini-TPC prototype	
Prototype taking beam data in TPC mode with very simple electronics	
Results show that performance goals can be met	
R&D is ongoing in many directions	
Optimization of the TPC gas mixture	
Gain	ongoing
IBF	ongoing
Drift velocity	can be done
Diffusion	can be done
Discharge rates	planned
Optimization of the readout element	
Number of layers	planned
GEM design (pitch, cobra, etc.)	planned
Additional meshes	can be done
GEM structure (Cr-GEM)	ongoing
Other elements (μ-MEGAs, 3D-mesh)	can be done, lesser priority
Technical R&D and calculations	
Optimizing chevron design	ongoing
Field cage	ongoing
Laser system	planned
Electronics integration	planned
Facility upgrades and Q&A lines	planned/ongoing